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THE ENDOWMENT OF ASTRONOMICAL RESEARCH.

THE unexampled prosperity of the United States, during the past few years, has given it the industrial supremacy of the world in many departments. A similar advance is to be expected in its scientific progress, especially in astronomy, if equal skill is shown in organization and development. The vast fortunes now being accumulated must, during the next few years, lead to gifts and endowments on a scale unparalleled in the past. It is not an easy matter to make large gifts wisely, and probably many of the most brilliant men in the country, having amassed large fortunes, are now trying to decide how they can bestow them to the best advantage. To establish a university of the highest grade a large sum of money is required. For instance, Harvard for many years has had an annual income exceeding a million dollars. To duplicate

the buildings, collections and other parts of the permanent plant, many millions would be needed to equal it even pecuniarily. Even then, a rival institution would be established, which might do more harm than good, since it would draw its students mainly from those who would otherwise go to existing universities.

Astronomy is a science which has always received a large share of such gifts as those mentioned above. Its rapid growth, at the present time, and the brilliant results obtained by the application of photography, spectroscopy and other branches of astrophysics, render it probable that it will still further attract the patrons of science. Unfortunately, in the past, many gifts have been made to astronomy which have not yielded the results expected from them. Thus we had at one time in the United States a great observatory, but no telescope; a great telescope, but no astronomer to use it; and an astronomer whose valuable observations, the results of many long years of hard work, were rendered useless by the lack of a few hundred dollars to publish them. We have still many beautiful observatories, equipped with powerful and expensive telescopes which are idle, and therefore useless, during a large part of the night. These unfortunate results are largely due to lack of consultation with astronomers by prospective donors. Consequently, many gifts have been made from which little return has been obtained.

While, as shown above, there are but few persons with fortunes large enough to establish a university of the first class, a much smaller sum would be required to establish an astronomical institution, whose usefulness would far exceed that of any now existing, especially by utilizing the plant already collected. The five observatories having the largest annual incomes are the U. S. Naval Observatory, $85,000; Paris, $53,000; Greenwich, $49,000; Polkowa, $48,000; Harvard, $50,000. The permanent endowment of the Harvard Observatory has increased from $176,000 to $909,000 during the last quarter of a century. These funds are invested by the treasurer of the university, together with the other funds in his charge, which now exceed $14,000,000. This large sum permits a very advantageous investment to be made, and during the last year the net rate of interest, free from all taxes, has amounted to four and eight tenths per cent. The age of the university, two hundred and sixty-seven years, insures great permanency in its management. It has passed uninjured through the periods of two great wars, and the great fire of Boston in 1872, which was still more disastrous to its supporters. Although the citizens of Boston lost many millions of dollars in this fire, this did not prevent their making good the heavy losses of the university. The strong interest and support of the people of eastern Massachusetts, which has led to their giving many million dollars to Harvard, is the best assurance that money intrusted to it will be spent as the donors wish.

It is estimated that the total sum spent yearly on astronomical research throughout the world amounts to about $500,000. It has been pointed out by Professor Newcomb that an addition to this sum of even $100,000, distributed among existing observatories, might increase the amount of work done, but would not necessarily improve its quality. Owing to the great industrial prosperity of this country, gifts may be expected ten times as large as those of the last century, during which this observatory received three funds exceeding one, two and three hundred thousand dollars, respectively. This seems, therefore, a proper time to consider how a gift of one

or two million dollars, if given to Harvard for astronomical purposes, could be best expended, and to see if the advantages would not prove so great as to induce some lover of science to make this gift. The great sums expended on astronomy in the past have developed elaborate systems of work and expensive instruments, such as have not been furnished in any other science, and have given astronomers a training in carrying on work on a scale not attempted in the other sciences. This, however, renders it necessary to expend large sums in order to attain better results than are now secured, and to make a real advance. It should be pointed out that it is as important to prevent gifts under improper restrictions, as to secure those that can be wisely expended. In the first case, not only is no useful result attained, but other donors are discouraged by seeing money thus wasted. It is also a matter of the greatest importance that the donors should see and appreciate the results attained, so that they may in this way receive a partial return for their enlightened generosity.

The policy of this observatory has been to secure and retain the interest of donors, and, when beginning on a small scale, to obtain results that justified extension. Thus, in 1882, an appropriation of $500 was secured from the Rumford fund, for investigations in astronomical photography. With this a camera of two and a half inches aperture was purchased, and stellar photographs taken, which led to an appropriation of $3,000 from the Bache fund. An eight-inch photographic telescope was procured, and with this thirty thousand 8×10 photographs have been taken. After being used on the northern stars in Cambridge, this instrument was sent to Arequipa, Peru, where it is now used throughout every clear night. The results proved of such value that Mrs. Henry Draper gave a second eight-inch doublet, to replace the Bache telescope in Cambridge. Thirty thousand photographs have been taken with this instrument also. Again the results were used to secure a still larger instrument, and, in 1889, Miss C. W. Bruce gave $50,000 for the construction of a twenty-four-inch photographic doublet, the most powerful instrument of the kind in the world. This instrument is also in successful use at Arequipa. As the photographs increased rapidly in number, the room for their storage and examination proved wholly insufficient. Again the friends of the observatory came forward and provided it with an adequate fire-proof building for their accommodation. Finally, this last year a grant from the Carnegie Institution has given us the means of beginning a systematic study of these plates, and thus extracting a few of the vast multitude of facts accumulated on them.

The three principal sources of income of the observatory, the Paine fund, the Boyden fund and the Henry Draper memorial, were all received after arguments had been presented showing the results obtained on a small scale. Fortunately no restriction was attached to either of these gifts that would interfere with its usefulness, and the income of the observatory can be expended in almost any way that will secure the greatest scientific return.

Another policy of the observatory has been one of cooperation, the last example being in determining the brightness of a system of standards of magnitudes for very faint stars. By the help of an appropriation of $500 from the Rumford fund, suitable photometers have been devised and constructed, and the directors of the Yerkes, Lick and McCormick observatories have courteously cooperated with us, so

that a system of standard stars has been selected and measured, including some of the faintest stars visible in the largest telescopes. In this work, telescopes of 40, 36, 26, 15 and 12 inches aperture, including the two largest telescopes in the world, are working together.

It is also our policy to carry on work in whatever way the greatest scientific return can be secured, whether at Cambridge or elsewhere. A fund of $70,000, of which $10,000 is now available, has been given for this purpose. It may be claimed that it will be difficult to maintain permanently a policy of complete unselfishness, by which astronomers in other countries may be aided whenever they can do a given work better than we can. The answer to this is that no body of trustees is better qualified to enforce such a policy than the president and fellows of Harvard College. Apart from the broad views they have always maintained, it is obvious that they could never afford, with the great interests they have at stake, to fail to carry out the wishes of any donor.

In 1886 a pamphlet, entitled 'A Plan for the Extension of Astronomical Research,' was published by the writer. As a result, in 1890 the sum of six thousand dollars was given by Miss C. W. Bruce, to try the plan for one year, and, out of eighty-six applications, it was distributed as follows:

3. Professor W. W. Payne, Director of the Carleton College Observatory. Illustrations of the Sidereal Messenger.

6. Professor Simon Newcomb, Superintendent of the American Nautical Almanac. Discussion of contact observations of Venus during its transits in 1874 and 1882.

16. Dr. J. Plassmann, Warendorf. For printing observations of meteors and variable stars.

23. Professor H. Bruns, Treasurer of the Astronomische Gesellschaft. To the Astronomische Gesellschaft for the preparation of tables according to Gyldén's method for computing the elements of the asteroids.

27. Professor J. J. Astrand, Director of the Observatory, Bergen, Norway. Tables for solving Kepler's Problem.

29. Professor J. C. Adams, Director of the Cambridge Observatory, England. Spectroscope for the 27-inch telescope of the Cambridge Observatory.

36. Professor A. Hirsch, Secretary of the International Geodetic Association. To send an expedition to the Sandwich Islands to study the annual variation, if any, in latitude.

40. H. H. Turner, Esq., Assistant in Greenwich Observatory. Preparing tables for computing star corrections.

45. Professor Edward S. Holden, Director of the Lick Observatory. Reduction of meridian observations of Struve stars.

46. Professor Lewis Swift, Director of the Warner Observatory. Photographic apparatus for 15-inch telescope.

54. Professor Norman Pogson, Director of Madras Observatory. Publication of old observations of variable stars, planets and asteroids.

57. Dr. Ludwig Struve, Astronomer at Dorpat Observatory. Reduction of observations of occultations during the lunar eclipse of January 28, 1888, collected by the Pulkowa Observatory.

60. Dr. David Gill, Director of the Observatory of the Cape of Good Hope. (1) Reduction of heliometer observations of asteroids. (2) Apparatus for engraving star charts of the Southern Durchmusterung.

78. Professor A. Safarik, Prague. Photometer for measuring variable stars.

79. Professor Henry A. Rowland, Johns Hopkins University. Identification of metals in the solar spectrum.

These examples show how high a grade of application might be expected, and, of course, if successfully carried out, the quality of the work would continually improve.

The following outline of a plan will show how a sum of fifty to one hundred thousand dollars annually could be advantageously expended for astronomy by this observatory. A board of advisers, consisting of several of the leading astronomers of the country, would be appointed, who would meet once a year, or at first oftener, to consider how the available income could

be best expended in order to receive the greatest scientific return.

This board would consist partly of the directors of observatories who could expend portions of the income themselves, and partly of older astronomers who, having retired from active work, could decide without prejudice how the income could be expended to the best advantage by others. They would have authority to add temporarily to their number, astronomers who might be invited to participate in any special work, and who could thus take part in their discussions on equal terms. All expenses of this board would be paid from the income, and except for clerk hire these would be almost the only executive expenses. A circular letter would be sent to all astronomers, inviting application for aid and suggestions for methods of expending the income. If possible, close relations would be established with the trustees of all the research funds which could be used for astronomical purposes, to increase efficiency and avoid duplication of work. The most important duty of the board of advisers would be to consider each year what departments of astronomy were being neglected, and to secure the needed observations, or, if necessary undertake them themselves, or see that they were made at Harvard. As every astronomer is inclined to undertake the work which attracts him most, especially interesting investigations are likely to be duplicated unnecessarily, while laborious or unattractive investigations are neglected. This is particularly objectionable, since in astronomy, a science of observation and not of experiment, an opportunity once missed can in many cases never be recovered. As an example of needless duplication, fifty observatories agreed to observe the planet Eros during its opposition in 1900, but so far as known only two or three have made the reductions needed to render their observations of any value. When a plan was decided on it would be discussed by the entire board, and it is obvious that their combined experience would render serious mistakes less probable than when all depends on the judgment of a single individual, as is now the case. They could find the best man for a given research, and give him the best possible facilities for carrying it on. They could undertake larger and more difficult researches than a single observatory could attempt. It would be the power of many, instead of one, and of large, instead of restricted, resources. The opportunity offered to such a board of advisers, having control of the principal instruments of the country and a large sum of money available to set at work any particular corps of astronomers, ought to secure results far beyond those attainable at any existing observatory. All the advantages of a trust would be secured, with none of its objections. No one could object to a trust in wheat, for example, if its only object was to increase the quality and quantity of the crop, and to furnish it to consumers at the lowest rates, also to aid those not members of the trust in every possible way. In the present case, these conditions would be enforced by a body of men entirely unprejudiced, the corporation of Harvard College. It is universally admitted that in the industrial arts there is a great advantage in cooperation, and in carrying on work on a very large scale. The same remarks apply to scientific investigation, with the added advantage that the supply and demand are indefinitely great, so that the market can never be glutted.

Apart from the advantages to astronomy of such a plan as is here outlined, it is believed that it would serve as a valuable example to the other sciences, and the moral effect of promoting uniformity of purpose,

and friendly aid to one another, by astronomers of all countries, would encourage other donors. An incidental advantage of this plan is that it could be tried on a small scale, as for a single year, and the donor could thus see what results were likely to follow if he made the plan permanent.

Of course, every effort would be made to establish the closest relations with astronomers in general, as the object of the institution could not be attained if the work done was not regarded as advancing astronomical research in the best way. Much might be accomplished through existing societies and periodicals. Another matter of especial importance is that when an astronomer is aided who is qualified to carry on work in the best way, no restrictions should be made on the appropriation, which would in any way interfere with his obtaining the best results.

It will be noticed that this plan differs from those governing existing funds for research, in being active and not passive. While the trustees of other funds wait for applications, and then consider what appropriations can be made, it would be the aim of the advisers of this fund to learn what astronomers desired aid, what instruments now unused were available for work, and what valuable material remained unpublished, and consequently useless, for lack of means. Its special object would be to determine the needs of astronomers, to find what subjects were being neglected, especially those whose usefulness would be lost by delay, and, if possible, to take the necessary steps to secure their execution. Much might be done with existing funds, and it is believed that the trustees of such funds would, in many cases, welcome the means of expending the available income to the best advantage. The opportunities for good work are far in excess of the present means for supplying them. Even the great resources of the Carnegie Institution will be able to respond to only a portion of the excellent applications made to it for aid.

It is most important that unnecessary delays should be avoided. It often happens that an astronomer could undertake a piece of work at once, perhaps during a summer vacation, while after a delay of several months he might be unable to carry it out, or might have lost many of the details then fresh in his mind. This is still more important with large pieces of work. A delay of several years may render a mature astronomer incapable of completing a work which, if undertaken at once, he could carry out with his greatest vigor and skill.

These remarks apply with equal force to the present plan of work. The Harvard Observatory has now the appliances, both intellectual and physical, for undertaking large pieces of work. Several of the leading astronomers of the country are in sympathy with such a plan for cooperation, so that the important methods of organizing and initiating a system could be devised at the present time under very favorable conditions, which may not prevail a few years hence, although the plan, once started, could easily be carried on by others. It therefore seems wise to make a beginning, however small, hoping to show results that will lead to an early fulfilment of the entire plan.

The undersigned, therefore, invites the astronomers of this and other countries to send to him applications for aid. A brief statement of the case in form for publication should be made, generally not exceeding two hundred words in length, with an estimate of the cost, and any additional necessary details. If publication is not desired, it should be stated.

The undersigned will then use his best efforts to secure the execution of such of

these plans as commend themselves to him, reserving the right to omit all others. If the list of applications received seems worthy of it, he will publish and distribute it to possible donors, and will endeavor to secure its publication elsewhere. He will also bring such applications as commend themselves to him to the attention of the officers in charge of the following research funds, with which he is officially connected:

Rumford Fund of the American Academy. Principal, $52,000. Income available to aid American investigators in light and heat.

Elizabeth Thompson Science Fund. Principal, $26,000. Income available for investigators of all countries in all departments of science. Appropriations seldom exceed $300.

Henry Draper Fund of the National Academy. Principal, $6,000. Accumulated income April 15, 1902, $1,515.99. Available for investigations in astronomical physics, by citizens of the United States.

Advancement of Astronomical Science Fund of the Harvard College Observatory. Principal, $70,000, of which $10,000 is now available as stated above. Income may be used for astronomers of any country.

When we consider the great sums at the disposal of the trustees of the Carnegie Institution, and the large unexpended balances of the various research funds of the National Academy, it is not probable that any really worthy investigation requiring only a few hundred dollars for its execution need fail for want of such a sum.

There is another direction in which the writer believes that a great astronomical return could be obtained for a reasonable expenditure of money, some of which is already available. There are, in the United States, many telescopes of large size, which are now in use during only a small portion of every clear night. It is believed that in many cases advanced students in astronomy would be glad to undertake systematic observations with such instruments, for a salary equivalent to a fellowship. They would thus be enabled to continue their studies, and at the same time make valuable additions to our knowledge of astronomy.

Larger investigations may be carried on by the Carnegie Institution, or by private gift. For such investigations the undersigned offers assistance to prospective donors, *if they desire it.* He will, in that case, secure for them the opinions of the leading astronomers of the country, regarding any proposed investigation. A wealthy man, when making a large investment in an industrial enterprise with which he is not familiar, would always obtain the opinion of an expert, for which he would often pay a large sum. How much more important is it in a subject like astronomy, with which he is likely to be still less familiar, that he should learn the views, which would be given freely and without charge, of the principal experts in the country who have devoted their entire lives to the consideration of these subjects.

It is believed that there are many cases where great results could be obtained from a relatively small expenditure. This is illustrated by the following examples:

A Northern Photographic Durchmusterung.—One of the greatest astronomical enterprises of the nineteenth century was the 'Northern Durchmusterung' of Argelander. This consists of a catalogue giving the approximate places and magnitudes of 324,189 stars, north of declination $-2°$, or practically north of the equator. This has been extended by his successor, Schönfeld, to declination $-23°$, including 133,659 stars, and successively to $-32°$, 179,800 stars, $-42°$, 160,415 stars, and $-52°$, 149,447 stars, by Thome at the Cordoba Observatory, where its extension to the South Pole is now in progress. Meanwhile, photographs taken by Gill at the Cape of

Good Hope have been measured by Kapteyn, and have given us the 'Cape Photographic Durchmusterung,' which contains 454,875 stars from $-19°$ to the South Pole. The errors in right ascension, of the positions in the Durchmusterungs of Argelander, Schönfeld and Thome, are about 9″, 6″ and 7″, respectively. The corresponding errors in declination are 26″, 10″ and 14″. The errors in the 'Cape Durchmusterung' are only about 3″ in each coordinate.

Professor Kapteyn, notwithstanding the long and laborious work he did gratuitously on the 'Cape Durchmusterung,' is willing to undertake the supervision of a similar catalogue of the northern stars, thus completing the work for the entire sky. Of course his past experience renders him the one man especially fitted for this work, which he could carry out in Holland so economically that it is probable the work could be completed by the expenditure of $25,000 during the next ten years.

The catalogue would contain about 900,000 stars, and would occupy ten quarto volumes of 300 pages each. Professor Kapteyn also believes that with a new measuring engine, which would cost $2,000, the errors could be reduced from 3″ to 1″. The cost of reduction would thus be increased, but by an amount which could be closely estimated before the work was undertaken. This is perhaps the most advantageous expenditure of money for astronomical purposes that can be made at the present time. The donor would be sure of the constant remembrance and gratitude of future astronomers. The matter is so important that this observatory would undertake to contribute without charge all the photographs needed, as its share of the enterprise.

As another illustration, the Georgetown College Observatory is about to establish a southern station in Rhodesia, South Africa. Father Goetz, S.J., will take charge of this work, and is now on his way. For $3,000 a twelve-inch telescope can be purchased, mounted and used, so that the excellent catalogues and charts of variable stars, completed for northern regions by Father Hagen, could be extended to the South Pole. As the cost of a first-class twelve-inch lens alone is about $3,000, we may regard the mounting, observatory and time of the observer as gratuitous contributions.

If donors could be found who would carry out such schemes as these, it is believed that the supremacy of the United States in astronomy might be placed on a foundation as secure as its industrial supremacy is in any department of work.

In brief, it is proposed to establish an institution in connection with the Harvard Observatory, whose aim should be to advance astronomy as much as possible by making appropriations under the combined advice of the leading astronomers of the country. Much attention would be paid to neglected subjects, especially to those which can not be provided for by later observations, to secure for persons properly qualified the use of powerful telescopes now idle and therefore useless, and, in general, to secure for the person best qualified for any given research the best possible means of carrying it on. It would provide means for cooperation, and would aim at the advancement of astronomy, regardless of country or any personal considerations. The cost of this plan, if fully carried out, would be less than that of a first-class observatory, and it could be fairly tried for a short time, at a moderate expense. For success, it must be wholly unselfish, and, this condition permanently secured, the

investments must be safe and the net income large. It is believed that no guardian would more surely fulfill these conditions than the corporation of Harvard College.

EDWARD C. PICKERING.

CAMBRIDGE, MASS.,
April, 1903.

THE NATURE OF NERVE IRRITABILITY, AND OF CHEMICAL AND ELECTRICAL STIMULATION. PART II.

THE present paper contains results confirming and extending those given in my paper in SCIENCE, Vol. XV., pp. 492–498, 1902. The results previously reported were interpreted to mean that chemical stimulation by salts, apart from the osmotic stimulation of strong solutions, was really an electrical stimulation due to the electric charges of the dissociated ions. Of these ions the negative or anion always tended to stimulate the nerve, while the positive or cathion always tended to reduce nerve irritability and prevent stimulation. Whether any salt stimulated or annihilated nerve irritability without stimulation depended upon the predominance of the anion or the cathion. Chemical stimulation was shown to be in reality electrical, instead of electrical stimulation being chemical as had hitherto been supposed. These results made it possible to understand electrotonus and electrical stimulation. The cathode increases nerve irritability and stimulates, because in this region anions are predominant during the passage of the current; while the anode depresses because here the cathions preponderate. Stimulation on the break of the current was due to the reverse of these processes, the accumulated anions diffusing toward the cathions, and a fall in the positivity of the nerve in the anode region resulting. Furthermore, the specific action of the ions upon the nerve was supposed to be due to a production of a change in state in the colloids in the nerve, extending Loeb's hypothesis in this particular and making it specific that stimulation meant a precipitation of the colloids, inhibition the reverse; the colloids of the motor nerve reacting as if they were electro-positive.

Since the publication of this paper, illness and the pressure of other work have prevented my bringing the matter to a conclusion as soon as I had hoped, and meantime Loeb has published an attack on my hypothesis so far as it applies to muscle.*

Loeb has been led to abandon this hypothesis because of certain exceptions, among them being the action of barium chloride. Further work, of which the following is a preliminary statement, establishes, I believe, the truth of the main conclusions in my former paper, so far at least as motor nerves are concerned. In the case of the muscle I can not but think, from Loeb's results, that a careful study of apparent exceptions might show the same facts there, and explain these exceptions, as has been the case with the nerve. As regards the possibility of sensory nerves showing a different reaction to motor, Grützner long ago pointed out the fact that they were readily stimulated by potassium chloride and acids, while motor nerves were not. Every one knows that acids will stimulate some sensory end organs, presumably by means of the positive ions the acids contain. Knowing these facts, it was easy to infer that sensory nerves were electro-negative and were stimulated by salts having a predominant positive ion, while motor nerves were electro-positive and were stimulated by the anion. Were this true, we should have a positive variation in sensory nerves and a reverse electrotonic effect from that in motor.

* Loeb, *Pflügers Archiv f. die ges. Physiologie*, Bd. 95, 1902, p. 255.